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Innovative Rinse-and-Recovery System for Metal Finishing Processes

Industrial Filter and Pump Mfg Co, Cicero, Ill

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This report describes the feasibility of a rinse-and-recovery system that can be installed in almost any metal finishing line and does not harm the environment because no plating solution exits to the sewer. Most toxic pollutants from metal finishing operations are associated with the water used to rinse the affected parts after successive finishing operations.

A typical car bumper plating operation was chosen as opposed to a barrel rolling operation. When a part emerges from the plating bath, it "drags out" full-strength plating solution with the bumper. This drag out is tremendously diluted by following rinse steps. The diluted rinses are sent to the sewer and cause toxic deterioration of the waste waters.

The ZDS™ is an innovative rinse-and-recovery system for use in the metal finishing industry. A conventional multistage aqueous rinsing system is replaced by a 2-stage solvent spray rinse followed by a single-stage aqueous immersion rinse. By continuously purifying and recycling the baths, appreciable savings in operating chemical costs can be realized.

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INNOVATIVE RINSE-and-RECOVERY SYSTEM

FOR METAL FINISHING PROCESSES

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This report has been reviewed by the Industrial Environmental Research Laboratory - Cincinnati, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report is a product of the above efforts. It evaluates a method of recovery of aqueous processing solution which, if not recovered, requires special treatment before it is eventually discharged into the nations' sewers and waterways. In particular, the report summarizes the effectiveness of this new method of recovery as applied to the metal finishing industry. It incorporates a rinse and recovery system different from the conventional counter-current rinses that follow a finishing operation. This new technology is to be identified as the Zero Discharge System™ (ZDS™). The ZDS™ is not only economically advantageous to the metal finishing industry but also is a possible effort to conserve and protect the natural resources i.e., chromium. No deterioriation of the environment is possible if the ZDS™ is implemented.

For further information on this subject, contact the Metals and Inorganic Chemicals Branch, Industrial Pollution Control Division.

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Industrial Environmental Research Laboratory
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ABSTRACT

This report describes the feasibility of a rinse-and-recovery system that can be installed in almost any metal finishing line and does not harm the environment because no plating solution exits to the sewer. Most toxic pollutants from metal finishing operations are associated with the water used to rinse the affected parts after successive finishing operations.

A typical car bumper plating operation was chosen as opposed to a barrel rolling operation. When a part emerges from the plating bath, it "drags out" full-strength plating solution with the bumper. This drag out is tremendously diluted by following rinse steps. The diluted rinses are sent to the sewer and cause toxic deterioriation of the waste waters.

The RIP™ is an innovative rinse-and-recovery system for use in the metal finishing industry. A conventional multistage aqueous rinsing system is replaced by a 2-stage solvent spray rinse followed by a single-stage aqueous immersion rinse. By continuously purifying and recycling the baths, appreciable savings in operating chemical costs can be realized.

An actual chrome plating bumper line was simulated for test purposes. After 80 hours of testing, the data shows that the levels of toxic hexavalent chromium was less than 2 PPM. Thus proving that the level of toxic drag out can be arrested.

This report was submitted by Industrial Filter and Pump Manufacturing Company in fulfillment of Grant R803721-01, given to the Bumper Recycling Association of North America, Inc., from the Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency. Work was completed on May 1976.

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SECTION 1

CONCLUSIONS

The heart of the ZIM™ is the multistage solvent rinsing technique. This technique exposes new technology which as its best application in the plating and metal finishing industry. As a result of multi-stage solvent rinsing, a non-polluted effluent exits the plant via the sewer.

This rinse-and-recovery system not only has excellent rinsing efficiencies but also recovers dragged-out chromic acid and returns it to the plating bath. In other words, a closed loop system has been achieved through the use of multistage solvent rinsing system.

An immiscible organic displacing fluid (IODF) acts as the main solvent flush that washes off the dragged out chromic acid. The solvent used is perchloroethylene, which does not deteriorate in the presence of inorganic acids and can be used repeatedly.

The goal of not degrading either air or water can be solved and full utilisation of metal finishing chemicals has been accomplished.

SECTION II

RECOMMENDATIONS

During the operating of the UM™ for over 50 hours, many suggestions were offered regarding improvements, but limiting factors of this pilot unit precluded making them. This is why it has been suggested and anticipated continuing development of this project.

It is recommended that the next phase of this project include the construction, installation, and operation of the UM™ in an existing chrome plating line. This project has given the necessary experience to successfully complete the next phase. An important objective would be to optimize the set-points and current flows as dictated by day to day finding. Another goal would be to develop data on the feasibility of a long-term (one month) recycling of plating baths and its effect on finishing quality.

Finally, this next phase will reassess the conservational impact of the UM™ on the National economy-chemical energy, and labor consumption. It will also determine its ability to achieve the 1983 Effluent Guidelines.

SECTION III

INVESTIGATION

GENERAL

The initial presentation of the multi-phase rinse and recovery method came from the Allied Chemical Corporation. Industrial Filter and Pump Manufacturing Company through the cooperation of the Bumper Recycling Association of North America, Inc. operated this system in Cicero, Illinois.

The RIM™ operates to return drag-out from rinse steps to the original process bath utilizing methods which economically collect and purify the recovered fluids. The net effect is to achieve a zero discharge system in an operation, such as plating, whose normal effluent discharges are toxic, undesirable, and expensive to treat. The RIM™ utilizes the best techniques previously available: countercurrent rinsing, ion exchange, and, in some instances, evaporation and/or reverse osmosis. It adds a further element of displacement by use of an IODF. This fluid provides an additional facet of rinsing that permits either fewer countercurrent stages or smaller deionization, evaporation, or reverse osmosis equipment. The effect is to provide rinsing in less space, time, and at less cost with a system that self adjusts for abrupt changes in drag-out volume or water loss volume from the process tank. For any process, there will be an economic optimization for the choice of RIM™ versus a simpler concept, such as a plain countercurrent rinsing.

OBJECTIVE

The purpose of this project was to demonstrate the effectiveness of a solvent rinse system. After a car bumper leaves the chromic acid plating bath, acid is normally dragged out through a series of rinses. However, by using an aqueous acid spray and an IODF spray, 99+% of this dragged-out plating solution is removed. The final rinse in these tests contained less than 2 parts per million (PPM) of chromic acid plating solution. After approximately 80 hours of testing, the final rinse tank, RT3 of Figure 2, was not contaminated with chromic acid.

THEORETICAL APPROACH

The RIM™ overcomes the major problems that can occur in standard countercurrent rinsing systems, such as the typical five rinse tanks connected in cascade (Figure 1). In such a system it has been demonstrated that the rinse ratio between successive rinses remains the same as that between the plating tank and the first rinse. By rinse ratio is meant the ratio of the concentration of the plating tank solution to the drag-out concentration after the first rinsing. This rinse ratio can also be shown to be equivalent to the total rinse water flow divided by the volume of the drag-out.

Assuming use of a chrome plating bath containing 200 of CrO_3 (chromic acid salt), with the initial rinse ratio at 10:1, the concentration in the first rinse tank would be 20 g/l. If good quality rinsing dictates that this be reduced to 0.002 g/l (2 ppm CrO_3) dragout residue on the work piece, using five rinse tanks with dragout volume being 100 l/day, a continuous rinse flow of 100 l/day would be required at the 10:1 rinse ratio.

Applying this analysis to a countercurrent system designed to operate at a rinse ratio of 4:1 (to equalize for a typical plating solution evaporation loss of 400 l/day), it can be shown that nine countercurrent tanks would be needed to produce the final 2 ppm CrO_3 concentration. If there were space for only three tanks, the rinse flow would have to be about 30,000 l/day, which would leave about 29,600 l/day excess water to be disposed of (if the evaporation loss from the plating tank were only 400 l/day). Whether the excess water was eliminated by restricted rinse flow (as with the 4:1 rinse ratio) or by another method, large capital outlays for equipment would be required together with high energy costs.

ACTUAL APPROACH

The RIM™ overcomes excess water usage and produces a final residual of 2 ppm using only three tanks (Figure 2). It should be noted that in the standard counter-current rinsing system, a fourth and possibly a fifth rinse tank is used. Parts move from the plating tank to the first rinse tank where they are sprayed with an acid pre-flush solution that is shown being returned from separator tank 1 at the first rinse tank concentration. This CrO_3 pre-flush increases the efficiency of the 100F rinse. Perchloroethylene is immiscible with the plating solution and, if used alone, would displace about 90% of the chromic acid.

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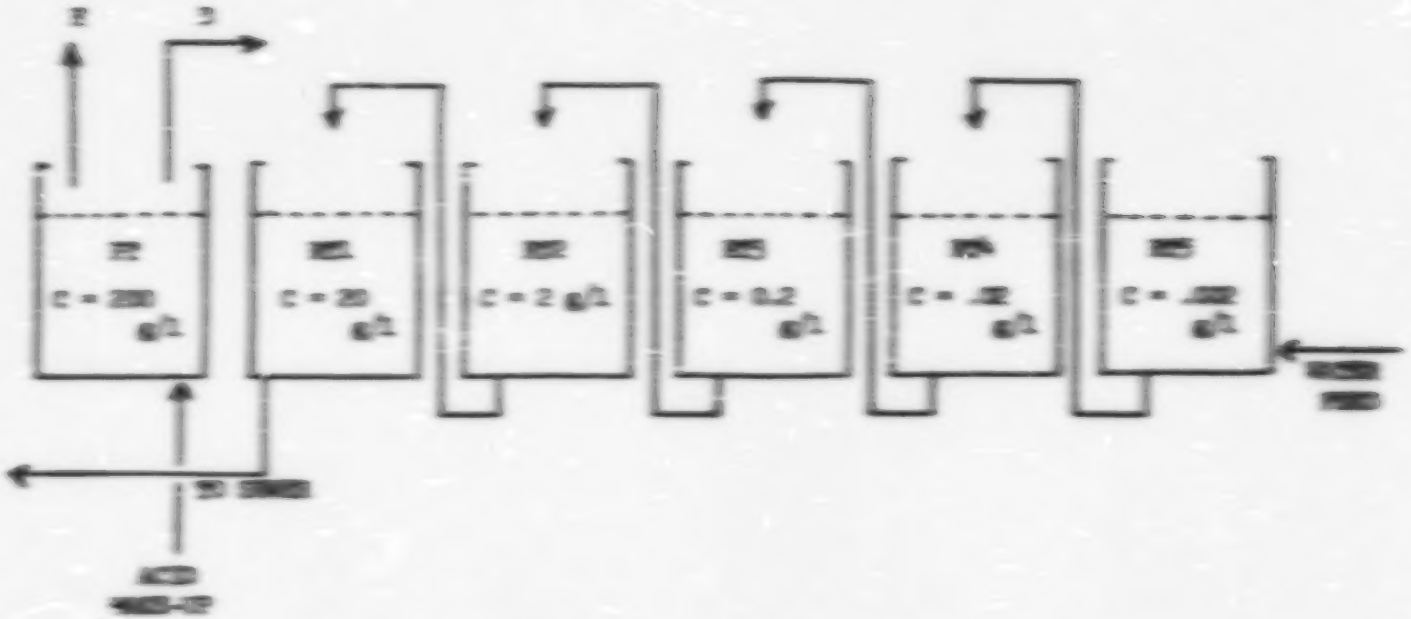

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PT = PLATING TANK

RT = Rinse Tank

D = Drag out of Acid on Work

E = Evaporation

C = Concentration of Acid

g/l = Grams acid per liter water

The first step, therefore, becomes a very important one. In the second rinse tank most of the remaining IODF is removed along with the plating residues. From separation tank 2 the recovered IODF is sent to the first stage to be reused and the dilute acid (Q_{aa}) is used chiefly for flushing in the second rinse tank. It should be noted that at the needle valve, some of the diluted acid is blended with about 0.05-.08% of the IODF. This dilute acid feed is identical to the forward feed of a countercurrent system. In other words, the dilute acid feed contains the same volume as the water advance as shown in Figure 8.

From tank 3, the rinse water circulates through the anion column where the hexavalent chrome is removed. The purified rinse is returned to tank 3 with a portion being used as forward feed for the second stage. Because the chromium recovered from regenerated anion resin must be reprocessed for reuse in plating, the deionization step is used at this point is only to achieve zero discharge with minimum outlay of capital and to conserve space.

After leaving separation tank 1 where the IODF has been removed, the aqueous effluent is sent to the Genesolv-D extraction unit (D in figure 8) to remove any residual (dissolved) perchloroethylene. (Perchloroethylene oxidation by CrO_3 when containing chloride ions could cause chloride ion buildup in the plating tank.) After the residual perchloroethylene has been removed, the remainder of the aqueous preflush (Q_{p1}) passes through the cation exchange resin to remove zinc, iron, copper, and other metallics, as well as trivalent chrome (Cr^{3}).

An evaporator (not shown) is required only if adequate evaporation is not occurring at the plating tank. This is relatively inexpensive when compared to eliminating 89,600 l/day of excess water, as mentioned in regard to the countercurrent rinsing example.

SECTION IV

DESIGN AND CONSTRUCTION OF THE SYSTEM

GENERAL

The entire EDS[TM] was constructed on four skids for shipment and ease of assembly (Figure 3). Skid number one contained the first separation tank, control cabinet, and all the necessary pumps and solenoid valves. The second skid contained the anion and the cation subassembly and the Genesolv-D (tri-chloro, tri-Fluoro, ethane) extraction unit. A vapor adsorber was on the third skid, and the chiller unit and second separation tank will be on the fourth skid. Vic Manufacturing Company had supplied the activated carbon vapor adsorber that was used.

SPACE REQUIREMENTS

The figures shown in Table 1 are approximate. Each system will ultimately have to be custom designed (at which time a more standard size layout can be developed).

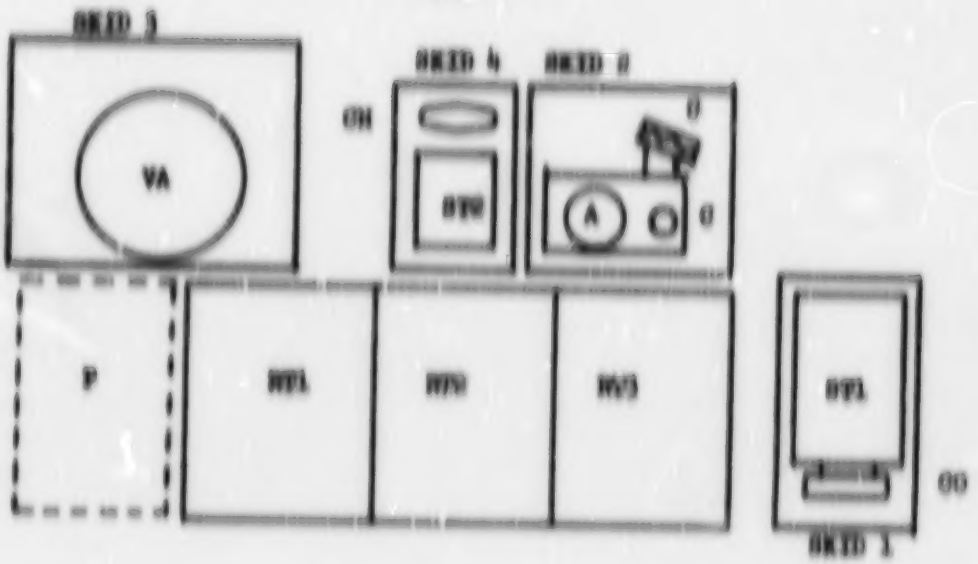
TABLE 1. SPACE REQUIREMENTS
(sq ft)

Component	Space
Vapor adsorber*	35
Anion and cation columns	10
Control cabinet and separation tanks	36
Piping and chiller	7
Total	90

*Two may be needed so that one can be regenerating while the other is being used.

FIGURE 3. ASG™ EQUIPMENT LAYOUT

TOP VIEW



LEGEND

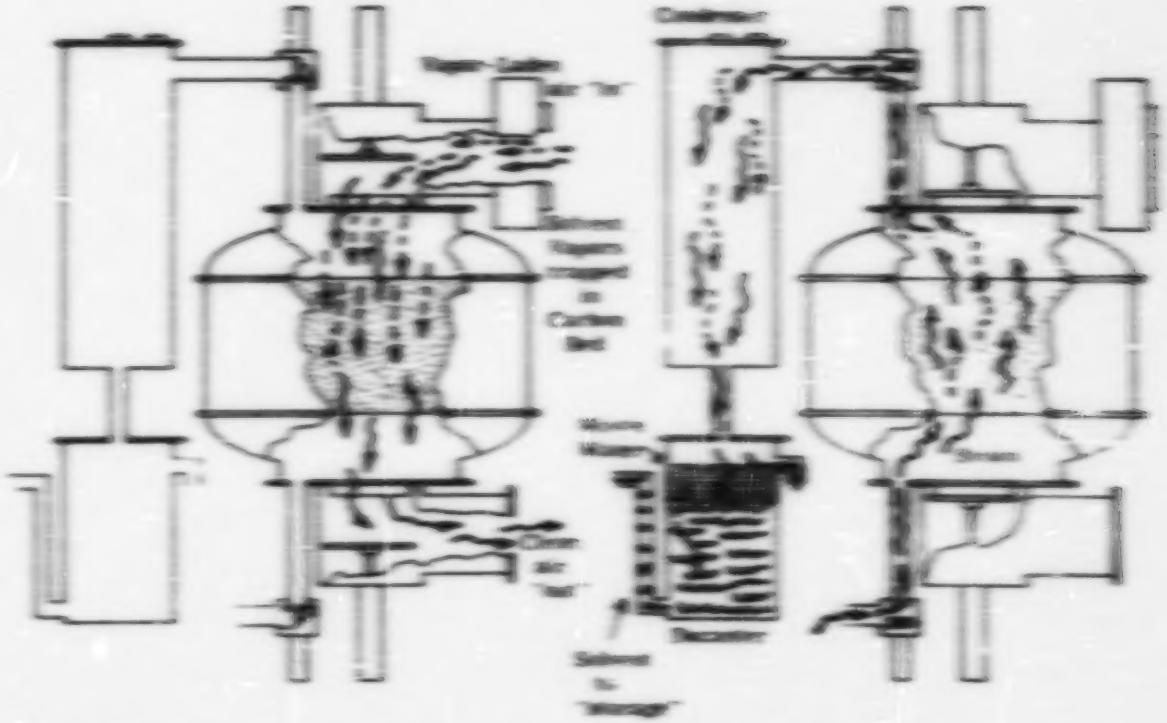
VA = Vapor Adsorber
P = Plating Bath
RT = Rinse Tank
ST = Separation Tank
A = Anion Column
C = Cation Column
D = Demineralizer-D
CH = Chiller
CC = Control Cabinet

OPERATIONAL REQUIREMENTS

With proper float controls and automated ion exchange columns, the [illegible] is fully automatic. This means that there are no additional skills required by the plating operator to run the system. Regular checks of the final rinse tank can assure that zero discharge will be met. Nothing other than normal maintenance is required to assure dependable service and long life.

VAPOR ABSORBER

The vapor absorber is used in this system to recover the sprayed perchlorosthylene. A mist is formed after the part has been sprayed in the first rinse tank. There are two cycles that are to be dealt with during the operation of the activated carbon absorber; the adsorption cycle and the desorption cycle. When the adsorption cycle is in proper operation, the vapor-laden air passes through the activated carbon. All of the solven vapors of perchlorosthylene are removed from the air stream (Figure 4). The vapor absorber system together with the lip vents (on the tanks) do an adequate job of recovering the solvent vapors from the equipment and the processing cycle. The unit was rated at 1100-1200 cubic feet per minute. In the desorption cycle, the regeneration of the unit was fairly simple and automated. Once the regeneration cycles have been determined, they can be timed on the control timer. (Manual control was used for this report.) The process requires that the unit be regenerated after 10 to 14 hours of processing, (150-200 bumpers rinsed) to ensure a 50% vapor-recovery efficiency. It is important to note that the desorption cycle is a closed loop cycle. Steam passing through the unit at a rate of 200-300 pounds per hour collects the perchlorosthylene from the activated carbon. The condenser water required was 2500 pounds per hour. The decanter assembly allows no perchlorosthylene to pass into the sewer. The retention time in the decanter assures proper separation of solvent and water to occur. When the unit has been regenerated, it automatically cycles back to the adsorption cycle. Any perchlorosthylene that is not removed is not allowed to escape because the flow is now reversed and the perchlorosthylene is sent back through the carbon. This unit has no air pollution capabilities because the solvent recovery loop assures clean air at low cost (Figure 4).



ADSORPTION CYCLE

DESORPTION CYCLE

ION EXCHANGE UNIT

This system requires a cation and an anion column assembly. In the tests, both columns performed as expected. The cation column removed all traces of trivalent chrome, iron, zinc, and copper in the recovery section of the system regeneration. After passing through the cation column, the chrome (Cr^{+3}) can be returned to the plating bath as make up. To protect the plating bath and the cation column from being contaminated by the perchloroethylene, the preflush chrome is passed through a Genesolv-D extraction unit to remove any perchloroethylene solvent. The anion column is used to remove any hexavalent chrome (Cr^{+6}) in the final rinse. Less than 2 PPM of hexavalent chrome was found in the final rinse after the first 80 hours of operation. Had this column been regenerated weekly, only a trace of chrome would have been recorded.

SEPARATION TANKS

After the bumpers are sprayed with the aqueous preflush and the EXDP, the effluent is allowed to drain into the separation tanks. Because the specific gravity of the aqueous preflush is 1.0 and the specific gravity of the EXDP is 1.6, these two fluids will separate from each other rather quickly. The solvent settles to the bottom of the separation tank so that it can be used over and over again in the spray tanks. The aqueous preflush floats to the top and is also re-used.

COOLING SYSTEM

The main purpose of the chiller unit is to create a cold layer of air in rinse tank 1 to reduce solvent vapor losses during the spray cycle. If a heated plating bath is used, it and the rinse tank should be physically separated to avoid unnecessary heat transfer. The chiller unit also cools the solvent in the separation tank and the small condenser on the Genesolv-D separator. The main cooling fluid used is ethylene glycol and water (50%-50%) mixture. Regular factory water is used in the vapor adsorber system. Although perchloroethylene does dissolve in water, during short project, none was detected. Special instrumentation is required to positively identify the dissolved perchloroethylene.

SECTION V

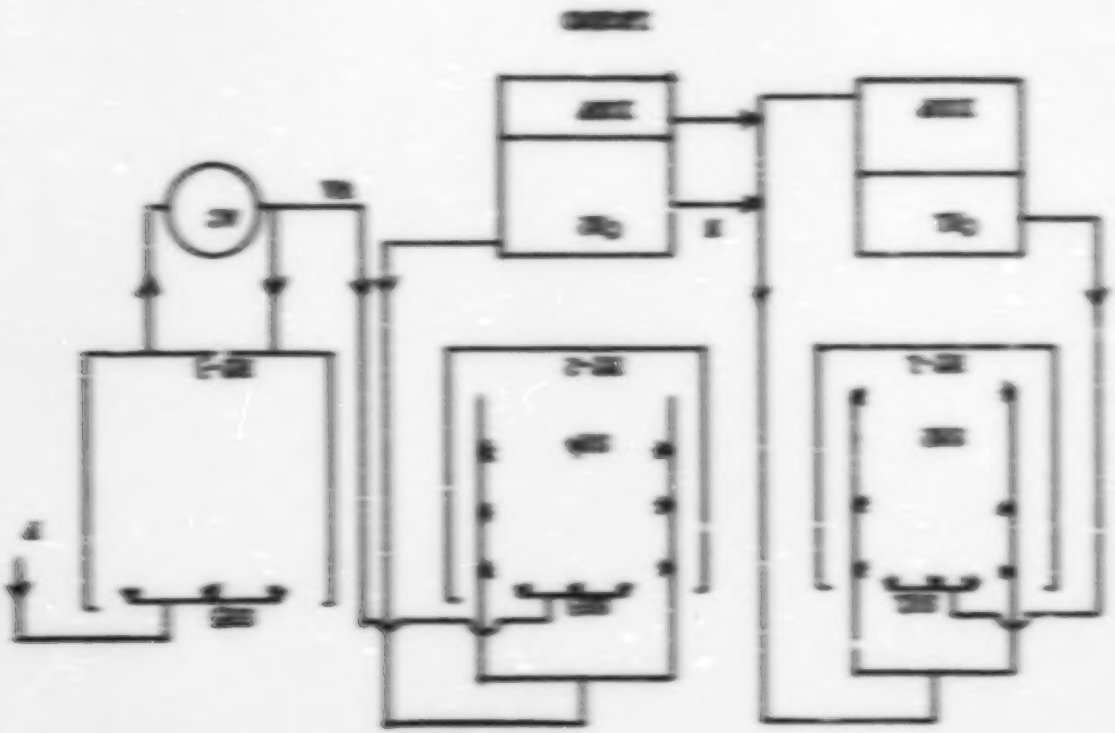
PROCESS DISCUSSION

The 2DS™ was designed for use in the metal finishing industry. For this particular design, car bumper sections were being plated. After leaving the chromic acid plating bath, the bumper was sprayed in the rinse tanks. The spray system is the heart of the 2DS™.

For the sake of clarity, it is necessary to define the terms that are used. The "aqueous preflush" refers to a dilute 1% mixture of chromic acid and water. The term "solvent rinse" refers to the perchloroethylene, which also is called 100F.

As shown in Figure 5, the aqueous preflush S-1 and solvent rinse S-2 are in the first rinse tank (RT1). The aqueous flushes S-3 and S-4 are in the second rinse tank (RT2). And finally, the water rinse S-5 (water feed, F) is in the third rinse tank (RT3).

As the work (in this case, a bumper section) is taken out of the plating bath, it is carried over and into RT1. As the plating rack is lowered into it, the aqueous preflush S-1 is manually (or automatically) actuated and is in force for 4-5 seconds. The main purpose of this aqueous prespray is to cool the work before the main solvent spray (this lowers the solvent evaporation and losses). The prespray removes approximately 50% of the chrome which is carried over on the work (drag-out) by replacing the drag-out concentration by the spray concentration (which should be 25% to 50% of the plating bath concentration). The spray rate is estimated to be 30-40 gpm. The next spray, which is actuated automatically at the end of spray S-1, is the main solvent spray, which is applied in such a way as to cover all of the work and maintain low evaporation losses. In this application, the solvent is sprayed at a rate of 18-20 gpm through 48 nozzles for 15-16 seconds. This volume is made up of 0.25 - 0.50% aqueous solution which is advanced from the second rinse effluent by the actuation of a pneumatic valve for the spray time. The work is then removed from RT1 and transported to the RT2. The data indicates that 95-97% of the chrome (plating solution) which was carried out from the plating bath is removed in the first rinse tank. Again, this depends on each individual application, the shape of the work, rinse system, rinse cycle time, etc. It is recommended, however, that a spray system always be employed in the first rinse tank to remove as much of the chrome as is possible, preferably 97-98% of the dragout.



The main purpose of RV2 is to displace the solvent which was left on the work after the first spray. Another reason is to remove some of the chrome which is left on the work after the first rinse. In this application, the rinse is actuated by a foot switch after the work is placed in the rinse tank R-2. The rinse system R2R is composed of 40 nozzles that spray at an approximate rate of 15-40 gallons per minute for 15-20 seconds. More impingement is required in RT-2 to remove the solvent remaining on the work after the first spray rinse (solvent) R1R. The concentration of the chrome on the work is again reduced to the aqueous spray concentration of spray R2R. For good rinsing efficiency, the R2R spray concentration should be a minimum of 100 times less the plating bath concentration. In this application a rinse spray (R2R) concentration of 1000-1500 ppm is acceptable. At the same time the main aqueous spray (R1R) of the rinse tank is activated, a rack spray is also activated. The principal purpose of this spray (RR1) is to advance water from the last rinse tank (RT1). This water advancement maintains a threshold concentration of the aqueous rinse in the second rinse system that is 100 times less than the plating bath concentration. As chrome is carried into the second rinse system as dragout, it is diluted to some concentration by the water which is advanced from the rack spray RR1. The water volume which is advanced through this spray is very small and varies depending on the water losses (evaporation) for each application. This water volume will also be approximately equal to the quantity which is advanced with each solvent spray in RT1. This increases the aqueous level in RT-2. The use of stainless steel nozzles (possibly having a smaller orifice) in a smaller quantity is recommended. Besides serving the purpose of water advancement, spray RR1 is a plating rack spray, i.e., the spray removes any chrome carried over on the plating rack so that it is washed off in RT2 and not carried over into RT1. In this application, after the 15-20 second spray duration in RT2, the work is removed and carried over to RT1. At this point (before the last rinse dip in RT1) more than 99% of the chrome should be removed from the work.

RT1 is an immersion water-rinse, whose concentration is maintained at a minimum (0 ppm) to ensure the removal of virtually all the chrome (99.99+%) from the work. Spray system RR2 over RT-1 serves as a rack spray to remove any chrome remaining on the plating rack. It is also a source of water supply to the system. Water feed may be continuous or on demand, depending on evaporation rate, nozzle size, etc. The chrome concentration is maintained low (<3 ppm) by continuously recirculating the aqueous rinse through an anion exchange column. During an 11-day test run, 1,105 bumpers were rinsed in the system.

SECTION VI

LABORATORY ANALYSIS

To accurately evaluate the EDE[TM], temperatures were recorded and samples were taken daily and sent to the laboratory for analysis. The samples were taken at: the plating bath (Table 2), the recovered chrome (Table 3), the first rinse (Table 4), the second rinse (Table 5), and the final rinse (Table 6). The samples were taken at the beginning and end of each day. Temperatures at these areas were also noted (Table 6).

TABLE 2. PLATING BATH

Sample	Total Chrome	Cr^{+6}	Cr^{+3}	Fe	pH
Taken after hours below	(ppm)			(ppm)	(10^{-pH}/liter)
After 1	NA	NA	NA	140	0.1
After 40	126,000	NA	NA	900	0.4
After 80	104,000	NA	NA	810	0.0

LEGEND

Cr^{+6} = hexavalent chrome

Cr^{+3} = trivalent chrome

Fe = iron

pH = strength of acid (moles H^{+}/liter)

ppm = parts per million

NA = Not Available

TABLE 3. RECOVERED CHROME

Sample Taken After Hours below	Total Chrome (ppm)	Cr^{+6} (ppm)	Cr^{+3} (ppm)	Fe (ppm)	pH (10^{-pH}/liter)
After 4	1,450	1,400	50	6.9	1.7
After 9	3,100	2,900	200	80	1.5
After 28	9,000	7,800	1,200	120	1.3
After 33	20,500	17,000	3,500	320	1.0
After 43	29,900	26,000	3,900	368	1.0
After 51	32,000	28,000	4,000	384	1.0
After 63	38,900	38,900	0	450	0.9
After 71	47,000	43,000	4,000	500	0.7
After 80	55,000	50,000	5,000	700	0.6

TABLE 4. FIRST RINSE

Sample Taken After Hours below	Total Chrome (ppm)	Cr^{+6} (ppm)	Cr^{+3} (ppm)	Fe (ppm)	pH (10^{-pH}/liter)
After 40	28,000	28,000	0	380	1.0
After 80	55,000	50,000	5,000	840	0.6

TABLE 5. SECOND RINSE

Sample Taken After Hours below	Total Chrome (ppm)	Cr^{+6} (ppm)	Cr^{+3} (ppm)	Fe (ppm)	pH (10^{-pH}/liter)
40	225	210	15	NA	4.0
80	700	705	55	NA	8.5

TABLE 6. FINAL RINSE

Sample Taken After Hours below	Total Chrome (ppm)	Cr^{+6} (ppm)	Cr^{+3} (ppm)	pH (10^{-pH}/liter)
1	0.0	0.0	0.0	6.2
8	0.0	0.0	0.0	11.5
16	0.0	0.0	0.0	11.8
24	0.0	0.0	0.0	11.0
32	0.0	0.0	0.0	11.0
40	0.0	0.0	0.0	10.8
48	0.0	0.0	0.0	11.0
56	1.0*	NA	NA	10.5
64	1.0	1.0	0.0	10.6
72	0.4	0.4	0.0	10.5
80	1.5	1.5	0.0	10.5

* Note: Here is an indication that column regeneration is required. This was not done during these tests.

TABLE 7. TEMPERATURE DATA (^{o}F) (AVERAGE 8-HOUR DAY)

Sample	Start	End
Solvent	68	92
Plating Bath	62	60
First Rinse	67	65
Second Rinse	66	70
Final Rinse	62	70

Under the tests conditions, the samples taken were not returned to the plating bath because it was at ambient temperature and required no make up of recovered chrome. The discharge of chrome was controlled as can be noted in Table 5 after 30 hours of operation. About 2 ppm of chrome were maintained in the final rinse. During this 80-hour phase of testing, the anion column was not regenerated. If it had been, no chrome would have been present, as shown after 50 hours. Also, proper column sizing is important to achieve maximum efficiency.

SECTION VII

COST

EQUIPMENT COST

The complete cost of one [illegible] was $16,400.00 as of May 1976. Assuming that proper ca[illegible]ance are given to the equipment, a 10-year life expectancy is anticipated. It is estimated that equipment costs will be about the same as those for alternative systems, except that the EDR™ requires less instrumentation. The real saving is realized in the recovery phase.

OPERATIONAL COSTS

Assuming 100 bumpers a day (500 bumpers a week) are run through the plating line, the costs incurred per bumper are:

Sulfuric acid (cation column)	$ 0.004
Sodium hydroxide (anion column)	$ 0.000
Perchloroethylene (spray loss)	$ 0.130
Genesolv-D (solvent extraction at column	$ 0.004
Steam regeneration	$ 0.010
	$ 0.168

It is estimated that the power consumed is the same for the EDR™ as it would be for a countercurrent rinsing system. This includes all the pumps and solenoid valves.

DRAWOFF

As previously discussed, the system uses perchloroethylene, which is available from several manufacturers at a cost of about $4 per gallon. The test data indicate that the solvent cost in the actual system application was approximately $0.13 per bumper. When compared with the cost of cleaning up the environment, this expenditure is quite reasonable.

SECTION VIII

OPERATIONAL PROBLEMS, SOLUTIONS, AND RECOMMENDATIONS

ADVANTAGES

The advantage of the RIM™ over conventional systems is in its rinsing efficiency and recovery portion. The conventional countercurrent rinsing system may require [illegible] of sulfur dioxide (SO_2) and one-half pound of sulfuric acid ([illegible] to reduce one pound of chromic acid (CrO_3). In 1975, 8,000,000 pounds of chromic acid were used in the bumper-plating industry, and it cost $1,250,000 to detoxify this acid. An additional one million dollars was spent to adjust the pH levels before dumping. Approximately 41,000,000 pounds of chromic acid are used annually for plating in general. Practically all this supply is imported from South Africa, Turkey, Rhodesia, and Russia. The RIM™ process recovers the chrome and returns it to the plating bath. RIM™ appears to be the best available technology if:

1. The evaporation rate is low (low-temperature bath)
2. A countercurrent system requires an excessive number of tanks
3. A reasonable size countercurrent system requires the removal of more than 5000 gallons/day of water
4. The magnitude of the difference in plating bath concentration and final rinse concentration is significant
5. There are significant fluctuations in evaporation or drag out volume

Therefore, the RIM™ should be given due consideration if any of these criteria are met. Finally, to date no adverse effects of this system on product quality have been encountered.

FLUOROCARBONTYLENE VS. FREON TF

The system cannot readily be converted to Freon TF, therefore no statement can be made on the possible advantages or disadvantages of using Freon TF. It is known that Freon TF has a low boiling point, 118° F, a characteristic that would cause it to flash off of the plated parts, thus making its recovery more difficult.

IRON CONTAMINATION

The first two-week test run disclosed that the recovered chrome contained too much iron. This indicated that either the cation exchanger was ineffective or too much iron was picked up in the unlined steel tanks before the recovered chrome was passed through the cation exchange unit. Sample analysis of the recovered chrome indicated that the iron and trivalent chrome (Cr^{+3}) concentrations increased proportionately, therefore, it can be assumed that the recovered chrome was corroding the steel tank (RT-1). All of the tanks should have been rubber lined at the outset to prevent the iron build up.

VAPOR ABSORBER

In the first series of tests (1000 cycles), approximately 30 gallons of solvent were lost -- over half of the total amount used. The equipment and test process should allow a solvent recovery rate of 80-90%. It was determined that recovery efficiency was poor because the vapor absorber was not regenerated until the end of the two-week test run. The unit should be regenerated at least every 1-1/2 days. A different lip vent design could be used to increase air flow and thus raise solvent recovery.

SPRAY ARRANGEMENT

Problems were encountered with the spray system. The material used to construct the spray headers in rinse tank R1 was chlorinated polyvinyl chloride (CPVC). It was attacked by the solvent perchloroethylene and the spray header arrangement and fittings fell apart after 1-4 weeks in continuous contact with the solvent. The other parts which were constructed of PVC (poly-vinyl chloride) seemed to be very resistant to the solvent and showed no signs of attack, cracking, softening, or swelling. It is recommended that the spray system be constructed of PVC or fiberglass.

ION EXCHANGE UNIT

No unusual problems were encountered with the anion exchange columns. Additional modification of the equipment was made to allow for water rinsing of the unit in a "downward" flow after the regeneration cycle. This included the addition of valves and fittings. A small water softener was constructed to permit the use of soft water for rinsing after regeneration. Besides the problems of iron and trivalent chrome buildup in the cation exchange column already described, additional

problems were encountered with the cation exchange columns. One of the columns began to leak before the test runs were started. The problem was finally resolved by using PVC glue generously at the leakage points. As with the anion exchange columns, additional piping and valves were required to allow for "downward" rinse action after regeneration. Before the recovered chrome is passed through the cation exchange column, it is passed through a column which is 1/4 filled with Allied Chemicals' Genesolv-D (tri-chloro, tri-fluoro, ethane). This mixing of the recovered chrome with Genesolv-D removes any traces of solvent perchloroethylene before the recovered chrome passes through the cation exchanger and is returned to the plating bath. All traces of solvent are removed to prevent the negative reaction of the solvent with the cation exchange resin. Also any solvent carried over may be detrimental to the plating bath. The Genesolv-D should be replaced once a week to maintain a high solvent absorption capability.

SEPARATION TANKS

The separation tank seemed to operate as anticipated. Additional piping was included to allow for the removal of solvent build up in the recovered chrome section of the tank. This modification continuously recycles the recovered chrome and any solvent which is carried over to the recovered chrome, thus preventing a large build up of solvent on the recovered chrome side. At the beginning of the two-week test run a leakage problem arose with the separation tank. One of its compartments twice had to be drained of the solvent and aqueous solution so that the tank side could be patched with viton and epoxy. The leaks occurred because chlorine had attacked the steel at the spots where welding was used to form compartment separation. The problem was probably caused by insufficient rinsing of the system when the unit was not operating (left dry). The chilling coils in the separation tank should be allowed to cool the solvent to 65-70° F. It has to be maintained at that temperature to reduce evaporation losses and to prevent heat build up (from pumps and process) from damaging the system pumps. Solvent feed to the system is actuated by a level control. Depending on the solvent losses incurred, the feed may be continuous or controlled manually on demand (when level drops too low in the separation tank). It was found that manual control (on demand) to be more satisfactory for solvent feed.

COOLING SYSTEM

The chiller unit experienced a freon leak prior at the beginning of the test run. The unit was repaired and is working satisfactorily. The main purpose of the chiller is to create a cold air layer in rinse tank #1 to reduce solvent vapor losses during the spray cycle. The heat transfer coils on the sides of rinse tank #1 seemed to do a good job in maintaining a cold layer of air in the tank. It is recommended that the plating bath and rinse tank #1 be separated by an air space in an actual plating installation. This would prevent or reduce the amount of heat transferred from the plating tank to the first rinse tank. As already mentioned, the chiller also cools the solvent in the separation

tank and the small condenser on the cation exchange unit. The cooling system is filled with an approximate 50%-50% ethylene glycol water solution. The unit is automatically set to maintain the temperature of the cooling fluid in the range of 15-30° F. Cooling water for the chiller compressor must be provided for the compressor to operate properly. In the two-week test run, only 1-2 gallons of cooling fluid were lost, probably due to evaporation.